MECHANICAL AND PHYSICAL PROPERTIES OF PLASTIC WASTE MIXTURE IN CONCRETE

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (BMMV) WITH HONOURS

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical and Manufacturing Engineering Technology

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in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this Choose an item. entitled "Mechanical And Physical Properties Of Plastic Waste Mixture In Concrete" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

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Date : 11 January 2023

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (BMMV) with Honours.

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Date : 20 January 2023

DEDICATION

I dedicate my dissertation work with a unique feeling of gratitude to my family and my friends, especially my mother, Intan Sapinat Binti Abdul Kadir. Thank you for love and support. Also give me some space to complete this thesis and project. Special thanks to my supervisor, Dr. Mohd Haizal Bin Mohd Husin, with his tremendous support and patiently given me guidance and teachings. Their words encourage and push for more persistence. I also dedicate this dissertation to my many friends who supported me throughout the process. I will consistently acknowledge all they have done. I am very thankful for these opportunities.

ABSTRACT

This thesis explains about mechanical and physical properties of plastic waste mixture in concrete. Dumping of plastic waste has become a serious issues as it is not properly handled. Reusing plastic waste, namely Polyethylene Terephthalate (PET), which is used as an aggregate in concrete component can reduce environmental pollution. Throughout this thesis, mixing method will be implemented where all the materials will be mixed together with various plastic waste mixture (PET) compositions in the concrete production. Besides, the effect of the influence of waste mixture (PET) in lightweight concrete based on the composition of waste mixture (PET) can be analysed after completed all the sample testing. In this research, preparation method played an important role for analysing physical and mechanical properties in terms of compressive strength, water absorption, density profile and moisture content. Different percentage of aggregate are selected in concrete mix design which are 1%, 3%, 5%, 6%, 8% and 10% composition of plastic waste mixture (PET). The process was started with raw material preparation and continue with preparation of PET aggregate into two sizes which are coarse and fine. The range size of coarse aggregate is 5 mm – 7 mm while for fine aggregate is 1 mm – 3 mm. In addition, there are five ratios of cement:sand being tested which are 1:1, 1:2, 1:3, 1:4 and 1:5 with total of 15 samples. Different ratios of samples are tested for compression test using Shimadzu Precision Universal Tester (Autograph AG-Xplus) to obtained the best ratio to be used as the benchmark sample of zero percentage of aggregate and to be proceed for sample fabrication. Concrete mix design is implemented with the ratio of 1:2 (cement:sand). During sample fabrication, all the prepared material are weighted according to the mix proportion and proceed with mixing process. The dry samples are then demoulded and ready to be tested for mechanical and physical properties such as compressive strength as well as water absorption, density profile and moisture content.

ABSTRAK

Tesis ini membincangkan tentang sifat mekanikal dan fizikal sisa plastik yang dicampur bersama konkrit. Lambakan sampah dari sisa plastik telah menjadi isu yang serius kerana tidak dikawal dengan betul. Dengan mengguna semula sisa plastik yang dikenali sebagai Polyethylene Terephthalate (PET) sebagai bahan campuran dalam konkrit, pencemaran alam sekitar dapat dikurangkan. Sepanjang tesis ini dijalankan, kaedah campuran telah digunakan iaitu dengan mencampurkan kesemua bahan sekaligus untuk membentuk satu komposisi baru menggunakan pelbagai amaun campuran sisa plastik dalam penghasilan konkrit. Selain itu, kesan yang mempengaruhi sisa campuran (PET) dalam konkrit ringan berdasarkan komposisi sisa campuran (PET) boleh dianalisis selepas pengujian sampel lengkap dijalankan. Dalam kajian ini, kaedah penyediaan sampel memainkan peranan penting untuk menganalisis sifat mekanikal dan fizikal dalam istilah kekuatan mampatan, penyerapan air, profil ketumpatan dan kandungan kelembapan. Peratusan berbeza untuk bahan PET telah ditetapkan dalam kajian ini. Antaranya ialah 1%, 3%, 5%, 6%, 8% dan 10% komposisi bahan sisa plastik PET. Proses dimulakan dengan penyediaan bahan mentah and diteruskan dengan penyediaan agregat PET kepada dua saiz iaitu kasar dan halus. Julat saiz untuk agregat kasar ialah 5 mm – 7 mm manakala untuk agregat halus pula ialah 1 mm – 3 mm. Sebagai tambahan, terdapat lima nisbah simen:pasir yang telah diuji iaitu 1:1, 1:2, 1:3, 1:4 dan 1:5 dengan jumlah 15 sampel. Nisbah yang berbeza telah diuji untuk ujian mampatan menggunakan mesin Shimadzu Precision Universal Tester (Autograph AG-Xplus). Ujian ini dijalankan untuk menentukan nisbah terbaik yang akan digunakan sebagai penanda aras bagi sampel yang tidak mengandungi agregat PET untuk diteruskan dengan proses penghasilan sampel. Kaedah campuran konkrit ini menggunakan nisbah 1:2 (Simen: Pasir). Sewaktu proses penghasilan sampel, kesemua bahan yang sudah disediakan telah ditimbang mengikut campuran perkadaran. Sampel yang telah kering dikeluarkan dari bekas acuan dan sedia diuji untuk mengetahui sifat mekanikal dan fizikal seperti kekuatan mampatan, penyerapan air, profil ketumpatan dan kandungan kelembapan.

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LIST OF SYMBOLS AND ABBREVIATIONS

F	-	Force
A	-	Area
mm	-	millimetre
cm	-	centimeter
N	-	Newton
kN	-	kiloNewton
g	-	gram
%	-	Percent
MPa	-	MegaPascal

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CHAPTER 1

INTRODUCTION

1.1 Background

Humans have relied on plastic as an inexpensive, adaptable, and durable material since the late twentieth century. PET, also known as polypropene, is a thermoplastic polymer used in a variety of applications such as food packaging, clothes, and building materials, and rit accounts for a significant portion of household garbage (Umasabor et al., 2020). PET is commonly used in the United States and is disposed after one usage. It is commonly utilized in the production of plastic bottles, food containers, and fabric fiber. PET stands for polyethylene terephthalate, which is a kind of polyester. It's frequently utilized in everyday things and is relatively easy to recycle. When stabilized, it takes on a semi-crystalline appearance. Because of its small weight, it is commonly used in rigid and flexible packaging. PET is one of those plastics that is used on a regular basis. PET is a fantastic choice for any application that requires a lightweight, impact-resistant material. PET is also one of the most widely recycled thermoplastics. Furthermore, ongoing attempts have been made to modify PET characteristics for greater performance with favorable cost profiles in order to meet high-end application demands.

As a result of plastic use, the buildup of plastic objects in the environment, such as plastic bottles and other items, has a negative impact on wildlife and their habitat, as well as humans. Plastic pollution is when a large amount of plastic is not recycled and ends up in landfills. Plastic garbage is thrown into unauthorized disposal sites in poor countries. The majority of plastic garbage in less developed countries ends up in the ocean, putting marine species in particular at risk. Due to affordable yet durable, plastic usage increases among consumers. Plastic, on the other hand, degrades slowly due to its chemical nature, posing a significant difficulty. To solve the problem of plastic waste in the environment, plastic consumption must be reduced and raise knowledge about plastic recycling. The main issue with plastics is that many of them are extremely durable and can take hundreds of years to degrade. This is producing severe issues, such as the accumulation of plastic pollution on land and in the seas. Each year, between 1.15 and 2.41 million tonnes of plastic are projected to reach the ocean, accumulating in vast offshore zones (Alhazmi, H. et al., 2021).

Many types of plastic garbage can be reused or repurposed in various ways. This study focuses on repurposing plastic waste, namely Polyethylene Terephthalate (PET), which is used as a concrete component. Concrete is made up of fine sand and coarse aggregate joined together with a fluid cement that hardens over time. After water, which is the most widely used building material, concrete is the second most widely utilized substance on the planet. Plastic aggregate in concrete can be used in building applications since it has the same strength as ordinary concrete (Alhazmi, H. et al., 2021). Aggregate can have a smooth or a rough surface roughness. Although a smooth surface improves workability, a rougher surface creates a stronger bond between the paste and the aggregate, resulting in increased strength.

According to Almeshal, I. et al., (2020), the impact of using poly-ethylene terephthalate (PET) as a partial sand substitute in concrete was investigated. PET was used as a partial substitute for sand in a batch of six concrete compositions, with substitution amounts of 0%, 10%, 20%, 30%, 40%, and 50%. Concrete was cast to test the workability, unit weight, compressive strength, flexural strength, tensile strength, pulse velocity, and fireresistant behavior of fresh and hardened concrete. A variety of typical experimental tests were undertaken with various amounts of PET in the research report. Five different percentages of PET were employed in the mixes, as well as a control mix with no PET. This method helps to conserve natural resources such as sand while lowering the self-weight of concrete in constructions. Although raising the PET replacement ratio affected the mechanical qualities of concrete, plastic particles can be encapsulated from other components to generate ecologically friendly concrete. Furthermore, recycled PET bottles can be used in a variety of applications include constructions where strength is not a concern.

There are several test that can be conducted to test the compressive strength and water absorption in plastic waste (PET) mixture in concrete. Basically it were compressive strength test and water absorption test. Compressive strength is the major physical characteristic of the concrete which is the one that is most commonly applied in concrete brick design (Umasabor et al., 2020). Compressive strength refers to a material's or structure's ability to hold weights on its surface without cracking or collapsing under the load's pressure. Besides, the water absorption test analyses concrete surface water absorption rate (sorptivity). It is durability property that is related to concrete.

1.2 Problem Statement

The problem of dumping plastic waste is quiet critical due to its non-biodegradable nature and making it can last hundreds of years in the environment. Plastic can caused pollution when not handled properly but it is also has many advantages such as durability. Therefore, many plastic waste can be reused or used for different purposes. Since plastic waste becomes one of the primary factor lead to environmental pollution, it can be reused in the lightweight concrete in order to overcome the challenge facing by society today. The most effective ways for solving this problem are by implement reduce, reuse and recycle activity. By using plastic waste, as to reduce the amount of sand in lightweight concrete is actually save costs of production in the long run.

1.3 Research Objective

Specifically, the objectives are as follows:

a) To produce plastic waste mixture (PET) in concrete production by using mixing method which are mixing all materials with various plastic waste mixture (PET) compositions.

b) To explain the effect of the influence of waste mixture (PET) in lightweight concrete based on the composition of waste mixture (PET) and preparation method for physical and mechanical properties in terms of compressive strength, water absorption, density profile and moisture content.

1.4 Scope of Research

The scope of this research are as follows:

- Production of plastic waste mixture (PET) in concrete with various percentage which are 1%, 3%, 5%, 6%, 8% and 10% composition of plastic waste mixture (PET) by using mixing method.
- Samples of waste mixture (PET) in the concrete that has been produced will be tested for mechanical and physical properties such as durability and compressive strength as well as rate of water absorption, density profile and moisture content.
- Samples of waste mixture (PET) in the concrete that has been produced will be compared to the reference sample (0% of aggregate) in terms of mechanical and physical properties.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Plastic and Polymers

The importance of plastic and polymers in the evolution of civilization can be summarized in a few terms. Plastics are a specific type of polymer that has a wide range of usage as a raw material for the manufacture of many new gadgets. As a result, not all polymers may be classified as plastics. By combining of monomer units polymer is generated with a large range of chemical and physical properties. Its presence may be felt everywhere, from little domestic appliances to massive industrial machinery (Hassan, T. et al., 2022). Its advantages include lightweight, durability, chemical inertness (in most situations). It has variety of additional mechanical features including as strength per unit weight, scratch resistance and hardness. Without polymer and its product in a world, all of these factors have made it impossible to imagine. They also have a significant negative influence on the environment. As a result, plastics products with other biodegradable materials is not enough as it can also be recycled to the greatest extent possible. As a result, it is currently one of the most sought-after research subjects.

2.1.1 About plastics and polymers

Polymerization is a fundamental chemical reaction that involves joining monomer units (Ethylene, Propylene) in a chain or a complex network using a specific chemical reaction mechanism, primarily addition and condensation. The most commonly used polymers in our daily lives, polyethene and polypropylene, come from crude oil and natural gas refineries (Hassan, T. et al., 2022). The polymerization process isn't restricted to a narrow area. Polymers have existed from the beginning of the cosmos and life, and a variety of natural polymerization processes have occurred in our environment.

2.1.2 Characterization of traditional polymers

The available production technology and desirable material qualities caused synthetic polymers produced from fossil fuels played an important role in polymer science from its inception. As a result, modern polymers made from renewable resources have unable to totally substitute their function. The fossil (polyethylene), PP (polypropylene), PET (polyethylene terephthalate), PS (polystyrene), and PVC (polyvinyl chloride) are still dominant in our modern applications because they are light, cost-effective, and meet the design standards. PE and PP, for example, are crystalline at room temperature and may be moulded. PET, on the other hand, has a glass transition temperature much above room temperature, giving it greater toughness and dimensional stability. It is self-evident that suitable testing procedures are required for characterization of any material in order to forecast its physical and chemical properties, which is the primary requirement of engineering product design. Today, various physical and chemical polymer testing methods are available, with many more in the research stage. (Hassan, T. et al., 2022). As the usage of recycled plastics has become more widely promoted as a means of achieving sustainable development, its characterization has become a key consideration in product design. For example, after being separated from undesired foreign particles, homogenized, and heat treated to give it uniform mechanical qualities, PET scrap appears to be recyclable. For a thorough mechanical analysis, its tensile characteristics, dynamic viscosity, and thermo-oxidative stability are investigated.

2.2 Introduction to Concrete

Concrete, which is made up of aggregates, water, and cement, is evaporating. Portland cement or its derivatives, the best commercially tracked and documented component, has been seeing tremendous growth from time to time (Van Damme, H., 2018). Concrete is used to produce foundations, columns, beams, slabs, and other load-bearing elements in building construction. Other than cement, several types of binding materials are employed, such as lime in lime concrete and bitumen in asphalt concrete for road building. Concrete is made in large quantities compared to other synthetic substance in the world. For concrete work, various types of cement are utilized, each with its own set of qualities and applications. Some of the type of cement are Portland Pozzolana Cement (PPC), rapid hardening cement, and Sulphate resistant cement. Construction uses almost double as much concrete and mortar as all other industrial building materials combined, including wood, steel, plastic, and aluminum. All of these infrastructures, including roads, bridges, tunnels, dams, power plants, ports, airports, dikes and seawalls, waste- and fresh-water facilities and networks, rely heavily on concrete, just as the foundations of our buildings, if not the entire buildings themselves.

2.2.1 Material, system and icon

Concrete is first and foremost a construction system, in which the material is inextricably linked to a way of implementation and building. It was already the case in the early days of the mid-nineteenth century, not long after the discovery of modern Portland cement, when a combination of aggregates, cement, and water was pushed between moveable forms to construct walls or to make arches in a barely wet state (Van Damme, H., 2018). When reinforcement was added to concrete, it made it even more system-like. Hundreds of patents on the subject were filed between 1870 and 1905, and the many companies that sprang up as a result of them all promoted concrete as a unique construction system with a unique combination of matrix, reinforcement, structural type, and construction method, sometimes with the help of early computation methods.

2.2.2 Reinforced concrete

Concrete can sustain high compression loads due to granular contacts dense network, but it can't withstand tensile forces because of porosity factor, fragile, and traversed by a plethora of water-covered surfaces. Reaching elastic limit causing it snaps abruptly. The same weakness exists in raw (unbaked) earth, although it is more pronounced. This did not stop architects from employing plain concrete or raw earth in their constructions if they chose the right architecture. The concept of using metal pieces to support buildings was not entirely original. In mediaeval and classical construction, metal tie rods were already used to keep stone walls from shifting. Metal reinforcement of mortar or concrete, on the other hand, follows a slightly different logic. The very essence of reinforced concrete is to "link the load-bearing to the load-carried parts" (Van Damme, H., 2018). It took decades to figure out how to do it using rebar of relatively small diameter in various configurations such as beams, slabs and columns. Although rebar reinforcement and pre-stressing increase the performance of structural parts, they do not affect the cementitious matrix. The matrix remains fragile and has a low impact resistance. The inclusion of discontinuous fibres that are short in respect to the size of the structural element but long in relation to the size of the largest grains is an easier way to add improvement for both the tensile strength (moderately) and the fracture energy (significantly) of concrete.

2.2.3 Concrete formulation

According to Van Damme, H. (2018) one of the properties of dense random packing of equal spheres is that its solid volume fraction is independent of sphere diameter as long as the local arrangement of particles is not perturbed by friction, non-contact, attractive or repulsive interactions, such as in fine powders, as is the case with hcp and fcc packing. This limit can simply be exceeded by cramming two or more populations of spheres together, without the need for complicated computations. Bernal's experiment performed with large or with small ball bearings would yield similar results, around $\rho \cong 0.64$, as long as short-range attractive forces do not perturb the game. Small spheres will fit in the interstices of larger spheres if their diameters are far enough apart, leaving even smaller interstices for the third generation of spheres to occupy. Not all concretes are designed to achieve the lowest feasible porosity with a given mix of aggregates, sand, cement, sand, and fillers, and not all concretes have a wide enough range of granular populations to use a fractal model.

2.3 Lightweight Concrete

Lightweight concrete is not a new development in technology of the concrete. They have been around since antiquity and are the forerunners of today's concrete. During the early Roman Empire, the first European references to lightweight concrete were created two thousand years ago. Over hundreds of years, it has astounded engineers from numerous disciplines by demonstrating the methodical utilization of various natural lightweight aggregates in opus caementitium. Due to the scarcity and irregularity of natural volcanic materials after the Roman Empire fell apart, the use of lightweight concrete was restricted. In the nineteenth and twentieth centuries, the creation and production of industrially generated lightweight aggregate was a watershed moment in material technology (Thienel et al., 2020). For lightweight concrete, the basic composition of as well as their interactions and mechanical qualities and durability effect, different from regular concrete. In comparison to regular concrete, this justifies raised attention and the majority of the design, production, and execution regulations need to be changed. As a result, this shows a fundamental overview of the main constituent, their qualities, and the special aspects connected with mix design and production. Some of the advantages of LC is can reduced dead load, faster construction speeds, and lower transportation and handling expenses. In the case of tall buildings, the eighth of the building in terms of the loads transferred via the foundations is a crucial factor in design. Because of the usage of LC, it was occasionally possible to continue with a design that would otherwise have been abandoned due to excessive weight. Using LC for building floors, partitions, and external cladding in frame structures can result in significant cost reductions. The haulage load for most building materials, such as clay bricks, is restricted not by volume but by weight. Much bigger volumes of LC can be hauled inexpensively with the right container design.

2.4 Waste management of PET Plastic

Our culture has developed an inconceivable world without the use of plastic in our daily lives. Its numerous benefits include good chemical, mechanical, and thermal qualities, as well as lightweight and low costs of production. Bakelite is the first synthetic plastic, was invented in 1907 and played a pivotal role in the development of the plastic industry. It has a wide range of applications in sectors such as food packaging, tools for medical, automotive and manufacturing. It is the most commonly utilized object in our day-to-day lives. The most widely used thermoplastic polymer in the world is polyethylene terephthalate (PET). PET is known as poly (oxyethyleneoxyterephthaloyl) referring to its systematic structure, according to IUPAC polymer nomenclature. It is known as Polyester in the industry of textile (Thachnatharen N. et al., 2019). Glass fibres and carbon are also added to boost the material's strength. PET is nevertheless quite sturdy despite its lightweight nature even without the inclusion of those elements. PET meets these qualities, making it a cost-effective packaging option because it uses fewer materials in the manufacturing process. PET packing adds very little weight to the packaged item and reduces the amount of fuel required to ship those things. It is semi-crystalline, translucent, and virtually shatterproof.

2.4.1 Current Techniques Used for PET Management

According to Thachnatharen N. et al., (2019), Chemical recycling, mechanical recycling, and PET waste degradation are the current methods for managing PET plastic waste. Chemical recycling of this waste is a process that involves many forms of depolymerization procedures to break down the polymers of discarded PET into valuable chemicals in the form of oligomers and monomers. Chemical recycling has the advantage of achieving the quality of virgin PET. Depolymerization employing a variety of methods, such as methanolysis, hydrolysis, glycolysis, aminolysis and ammonolysis is part of the PET waste chemical recycling. Glycolysis is an example of the most widely utilized methods of chemical recycling for PET plastic waste. Primary product of EG's deep glycolysis is bis-2-(hydroxyethyl) terephthalate (BHET). It can be used directly in PET production. The procedure is normally carried out at a temperature of 180 to 250 °C in the presence of excess EG and a transesterification catalyst, zinc or lithium acetate in commonly. Due to its non-biodegradable nature, mechanical recycling is one of the most effective techniques of managing PET trash. The PET plastic waste mechanical recycling involves several main phases, including plastic collecting, manual sorting, chipping, washing, and pelleting. Plastic collecting, manual sorting, chipping, washing, and pelleting are all phases in mechanical recycling (Thachnatharen N. et al., 2019).

PET degradation, which results in a drop in molecular weight and discolouration due to chain scission, is the final procedure. Extensive exposure to extremes of temperature, UV, visible light, microorganisms and moisture can cause this process to occur spontaneously. To accelerate the decomposition of PET waste, the degrading ingredient can be manually induced. For example, biodegradation is a great option to PET waste treatment since it is inexpensive, high efficiency, and does not lead to secondary pollutants production that PET waste incineration and landfilling do. Photodegradation of PET trash occurs naturally in the environment as a result of exposure to ultraviolet (UV) light from the sun (Thachnatharen et al., 2019). UV radiation gives out the activation energy needed to start the integration process.

PET has a lot of advantages, such as being lightweight, having a low cost of production and also a good stability of thermal. Because of its low cost, PET waste materials are always available and can be afford to the majority of people all over the world. As a result of the strong demand for PET materials around the world, mass production of these materials occurs. Because a considerable volume of PET trash is discarded into the garbage, sewers, and rivers, this has a negative influence on the environment (Thachnatharen N. et al., 2019). PET plastic waste is not biodegradable in the environment which lead to environmental pollution. It gives impact on humans, animals, and non-living things. PET plastic waste, on the other hand, can be recycled after it has been consumed. PET waste's recyclability must be viewed as a precious resource for the country. The problem of PET waste management can be solved with a collaborative effort from the public, government, and corporate sectors.

2.5 PET As Aggregates in Concrete

Plastic products mostly do not easily degrade in the natural environment which mean they should be recycled or re-used. Plastic can be divided into two categories based on whether it is reused or recycled refering to thermoplastics and thermosetting polymers. The thermoplastic can be reused shows one of the quality. Polyethylene (PET), and Polypropylene are examples of thermoplastic, which can be recycled (Chowdhury et al., 2018). Thermosetting polymer, on the other hand, is a type of plastic that has the opposite qualities of thermoplastics. As a result, it cannot be recycled but instead, it is often used as a filler in paint or other products, and the shape of the thermosetting polymer is reduced for that purpose; sometimes pulverized into finer forms, they're made into other products. This procedure is currently being carried out as plastic recycling. The molecules in thermosetting plastic have a different interlocking, which is referred to as cross linking. For instance, unsaturated polyester resin like epoxy resin. This kind of polymer is utilized in the tyres of a variety of vehicles. Rubber that is utilized in tyres is also recycled. This plastic is crushed into pieces and properly disposed of for recycling purposes.

2.5.1 Recycling Methods

According to Chowdhury et al., (2018), the solid waste could be regarded as the main source of recyclable materials. Many modern productions are dependent on the solid waste recycling. Example of solid waste is plastic aggregate and it has been a prominent material in a number of experiments. Laboratory assistance was used in investigations where using plastic bottles as aggregates. As the bottles used in the research need to be reshaped, thus it must be done in the laboratory. The bottles are mechanically crushed in the laboratory to assure the desired size, and then the ground particles are sieved. Finally, the desired size is discovered. Some industries employ propeller crushers or blade mills to convert plastic trash into an appropriate size. In some circumstances, sufficient sized plastic can be found at waste treatment plants or plastic production companies. Aggregates are processed in a variety of ways depending on their type and source. There are a few well-known procedures for making PET aggregates. The waste from the PET industry is collected and treated. The garbage is ground in this procedure. The process is called involuntary since it is carried out by an automatic mechanism. The particles are cleaned before and after the process. The alkaline solution is used to wash the clothes. The resulting particles are centrifuged to remove contaminants and then washed in water. Some contaminants, like as glass and glue, are removed during the treatment procedure. In addition, certain finer particles are produced. The de-dusting technique is used to remove the finer particles.

2.5.2 Uses of PET as Aggregate

Several research concentrating on the usage of PET in structural conventional and structural-lightweight concrete have been undertaken by various authors. Mechanical parameters such as flexural, compressive and tensile strength, elasticity modulus, pulse velocity, S–S curve, durability and slump density are all challenges that need to be addressed (Chowdhury et al., 2018). For example, granular PET waste aggregates made from unwashed PET bottles were studied as a concrete alternative, using 5% fine aggregate or natural sand and an equal weight of granular PET aggregates made from waste unwashed PET bottles (WPET). Although compressive strength of the cementitious materials reduced as a result of their trials, they also found a reduction in their specific weight and improvement that can be consider in their flexural behaviour after a peak. It is been discovered that when PET volume fraction and polycarbonate aggregates increased, the predicted flexural toughness factors increased dramatically. Furthermore, PET and polycarbonate (PC) plastic aggregates in cementation materials would provide good absorption of energy materials, which would be especially advantageous in applications of civil engineering such as structures subjected to impact or dynamic forces.

2.6 Recycled Plastic Partially Replace Sand in Concrete

Business of the lightweight construction materials is thought would give benefit in uplift the reuse of materials. Replacement of natural aggregates with lightweight materials typically results in a reduction in concrete unit weight. In the building sector, weight reduction is a critical goal. Lightweight concrete has several benefits which include saving cost in terms of money, a high thermal insulation response and save time spent handling and manufacturing it (Almeshal, I. et al., 2020). When flakes of PET plastic bottle are mixed with or utilized to substitute the aggregates in typical construction materials, such as concrete or bricks, the weight and density of the building material can be reduced. As a result, a lightweight but robust materials that may be employed in basic construction, for example the wall construction.

2.6.1 Material and Experimental Method

According to Almeshal, I. et al., (2020), Medcem ordinary Portland limestone cement was used according to EN 197-1. CEM II/A-LL 42.5 R was employed. Natural coarse aggregates with optimum sizes of 25 mm, 12.5 mm and 9 mm are utilized in the preparation of concrete sample, according to standards. Bottles made of polyethylene terephthalate (PET) were utilized. The thickness of the trash PET bottles is 1–1.5mm. The bottles were cleaned to remove contaminants, and then the PET waste is ground using a blade mill to size of 4 mm – 0.075 mm. In this investigation, natural sand that had not been pulverized was employed. The material's gradation utilized in this research is represented by the properties of sand, coarse aggregate and PET. To investigate the impact of PET on concrete characteristics, different replacement ratios were used such as 10%, 20%, 30%, 40%, and 50% in weighted combinations. PET was employed in five different percentages in the mixes, as well as one blend without PET. The ratio of water to cement was 0.54.

2.6.2 Concrete Mix Design

The concrete mix proportioning was calculated according to British Standard (BS). Natural crushed rocks which represent coarse aggregates were replaced with 0 percent, 10%, 20%, and 30% plastic aggregates, respectively, in this study. The aggregates combined specific gravity was computed to get the proportions of the mixture. The aggregates' fineness modulus and specific gravity were determined using a sieve test and a Pycnometer test (Lee, Z. H. et al., 2019). Casting and compaction were carried out in accordance with British Standard BS1881-108:1983. A vibrating table was used to compact the soil. When there is no air bubbles were visible on the surface and a smooth surface was achieved, vibration was turned off. To avoid moisture loss during concrete hardening, the casted specimens were covered. The specimens were removed from the mould after 24 hours. Then it is cured in water for 7 days and also 28 days, respectively. Curing process is carried out in conformity referring to British Standard 1881-111: 1983. Density and slump are tested in accordance with BS EN12350-6:2009 and BS 1881-102:1983, respectively, to evaluate the fresh concrete qualities. The hardened and dried concrete cubes was tested for it compressive strength at 7 days and 28 days in line with BS 1881-116:1983. The overall weight of concrete is lowered which resulting in lighter concrete due to the lower density of plastic aggregates when it is compared to natural coarse aggregates. Compressive strength of concrete containing chemically treated plastic aggregates is higher than the control PAC. The reason is cement paste and plastic particles having varying bond strengths.

2.7 Plastic and Concrete in Environment

Plastic raw materials are most typically derived from nonrenewable resources, such as fossil fuel sector products like styrene and ethylene. Plastics manufacture accounts for between 4% and 8% of world oil production, taking into account both raw materials and manufacturing energy. These are similar to the levels used in the aviation industry. A number of 'additives' can be added to the polymer during the manufacturing of both conventional and bioplastics to vary its character. Plastics can take on a variety of forms with variable looks, durability, and performance, as well as function differently in the environment, because of additives (Clunies-Ross, 2019). Entanglement with plastic pollution can injure animals, reducing their ability to move, feed, escape predators, and reproduce successfully. They will frequently die if they are unable to free themselves from entanglement. Several species, including birds and marine life are affected by this global concern. Fishing equipment that has been abandoned, misplaced, or discarded is particularly damaging to marine wildlife. Fishing nets, line, rope, and pots are all made to be used for a long time. These plastics do not dissolve well in the ocean, and a single piece of abandoned fishing gear can entangle, catch, and kill a variety of marine animals. Plastics are good for our health because they are used in medical applications and to safeguard our food and beverages. Plastic bottles and containers allow for the distribution of safe-to-drink water in areas where water contamination is a serious problem.

One of the most essential building materials is concrete, in terms of quantity and environmental impact. Manufacturing of cement is responsible for 5–8% emission of global carbon dioxide. The effect in not only in global warming, but also contibute to acidification and eutrophication. There are several environmental benefits can be obtained from this perspective which are stemming from a structure's endurance and the capacity to conform the environmental profile through construction optimization of material. Concrete mixtures become the first field of studies into reducing the environmental consequences of concrete. By including supplemental various of building materials and recyclable aggregates, alternative concrete mixtures have been devised (Walach, D., 2021). In traditional concrete technology, increasing the strength of mechanical of the concrete is associated with increasing the Portland clinker content, lead to a decrease profile of environmental (per cubic meter).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The methodology and the materials which were utilized are discussed in this chapter. Details on the material ratio used also reported in this section. The curing method and material preparation of the waste product and related machines used in this study are also described in depth in this section. Every step and procedures used in producing the samples included as well. Figure 3.1 shows the overview methodology of this study as preparing the plastic waste (PET) aggregate is a first step need to be done.

This research project mainly involved experiments and tests at several laboratories. These includes Material Science laboratory, which is located at Factory 2, and Testing laboratory at Factory 1, FTKMP, UTeM. Three main stages in the experiments involved collecting the waste products, production of concrete samples, testing on physical and mechanical properties of the samples. The tests covered comprehensive strength test and water absorption test

3.2 Research Setup

This research project mainly involved experiments and tests at several laboratories. These includes Material Science laboratory, which is located at Factory 2, and Testing laboratory at Factory 1, FTKMP, UTeM. Three main stages in the experiments involved collecting the waste products, production of concrete samples, testing on physical and

mechanical properties of the samples. The tests covered are compressive strength test, water absorption test, moisture content and density test.

3.3 Raw Material Preparation

PET plastic waste is the chosen aggregate to be used in this research. There are several advantages that can be achieved by using this aggregate which include disposal of waste and prevention of environmental pollution. It is also expected to produce a material with good energy absorbing, which would be particularly useful in a variety of applications in civil engineering such as when it is subjected to impact or dynamic forces (Chowdhury et al., 2018). Different waste mixture and proportion ratios are suggested to produce plastic waste mixture (PET) in concrete with various mixture compositions.

3.4 Preparations of PET Aggregate

In this research, plastic bottle with PET label that were initially collected mainly from households is sorted and cleaned by being rinse with water to remove dirt and impurities. From the Figure 3.1, the cap of plastic bottles are removed and the bottles are placed in upside down position to remove water inside the bottles and make it dried. This step was done to ensure that no remaining water that would break the covalent bonds in the polymer chain, which would result in decreasing molecular weight of the polymer and also reducing the mechanical properties of the plastic (Islam et al., 2022). The upper part and bottom part of bottles which are quite thick are removed by using paper cutter. Then, the body of the bottles are cut into spiral shape by using scissors. Lasty, the step is continue with cutting the spiral sheets of plastic into two sizes which are small and large pieces represent the fine and coarse sizes. The range size for fine PET aggregate is 1mm-3mm while for coarse PET aggregate is 5mm-7mm.

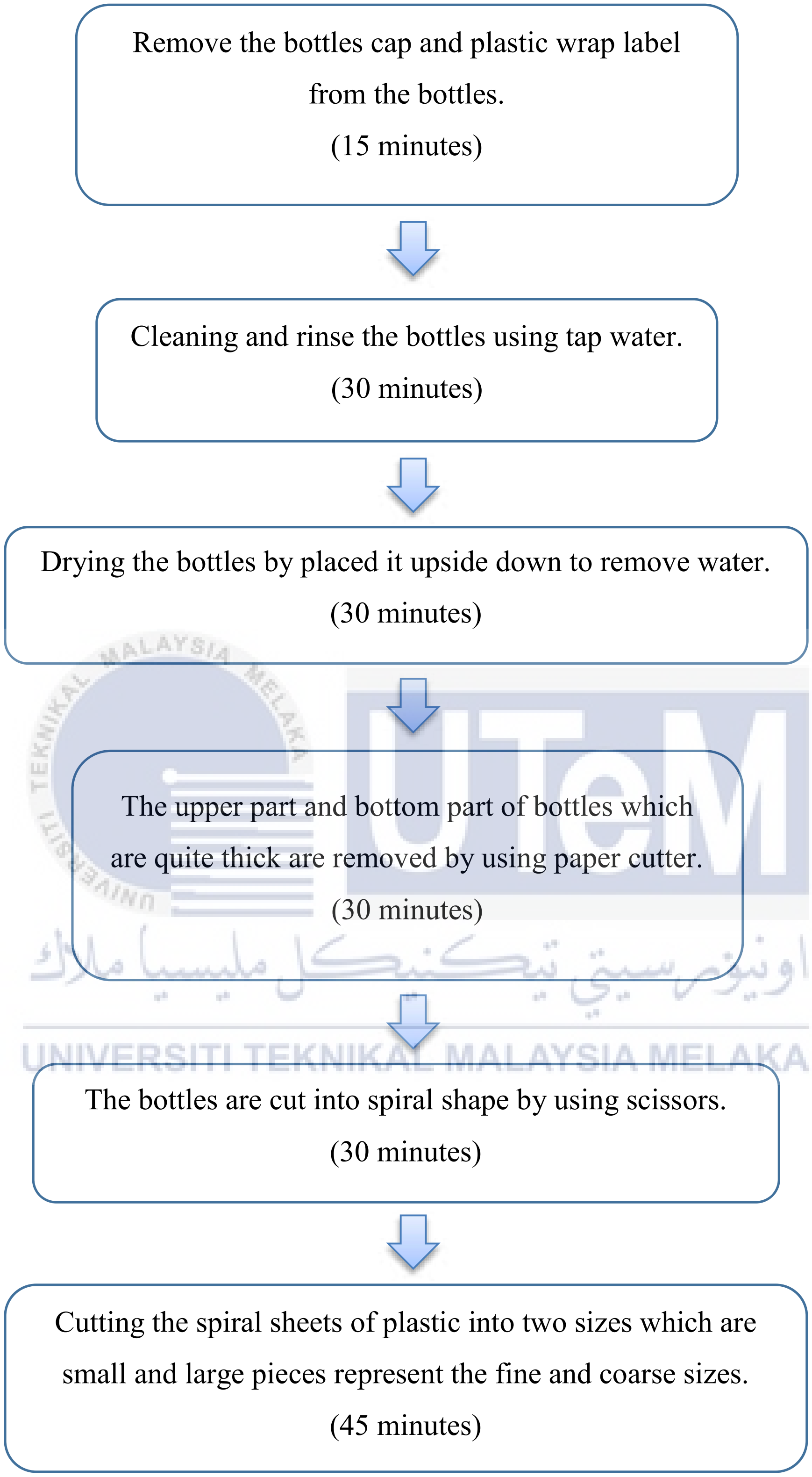


Figure 3.1 Preparation of PET Aggregate

3.5 Production of Plastic Waste Mixture (PET) in Concrete Samples

Generally, there are few general mixing ratios for concrete which are depends on the composition of cement: sand: aggregate (stone) according to that order. The waste material were used as partially replacement of aggregates. Table 3.1 shows the mix proportions of the materials.

Table 3.1 Mix proportions of the samples

No.	**Ratio of concrete, Cement : Sand (1:2) Mix with PET Plastic Waste**	
	Fine	**Coarse**
1.	0%	0%
2.	1%	1%
3.	3%	3%
4.	5%	5%
5.	6%	6%
6.	8%	8%
7.	10%	10%

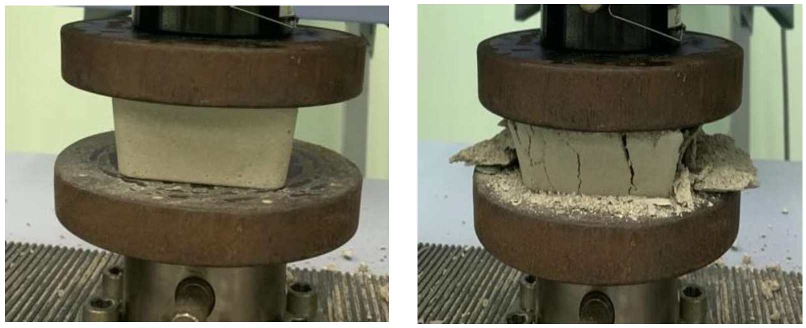
3.6 Ratio Selection

In this research, there are five ratios of cement:sand which are 1:1, 1:2, 1:3, 1:4 and 1:5 being tested for compressive strength test. The process started with sample fabrication. After the sample dried, it is weighted and ready to be tested using Shimadzu Precision Universal Tester (Autograph AG-Xplus). Figure 3.2 below shows the ratio selection using compression test while Figure 3.3 shows flow chart of ratio selection process.

Ratio 1:1

Ratio 1:2

Ratio 1:3



Ratio 1:4

Ratio 1:5

Figure 3.2 Ratio Selection Using Compression Test

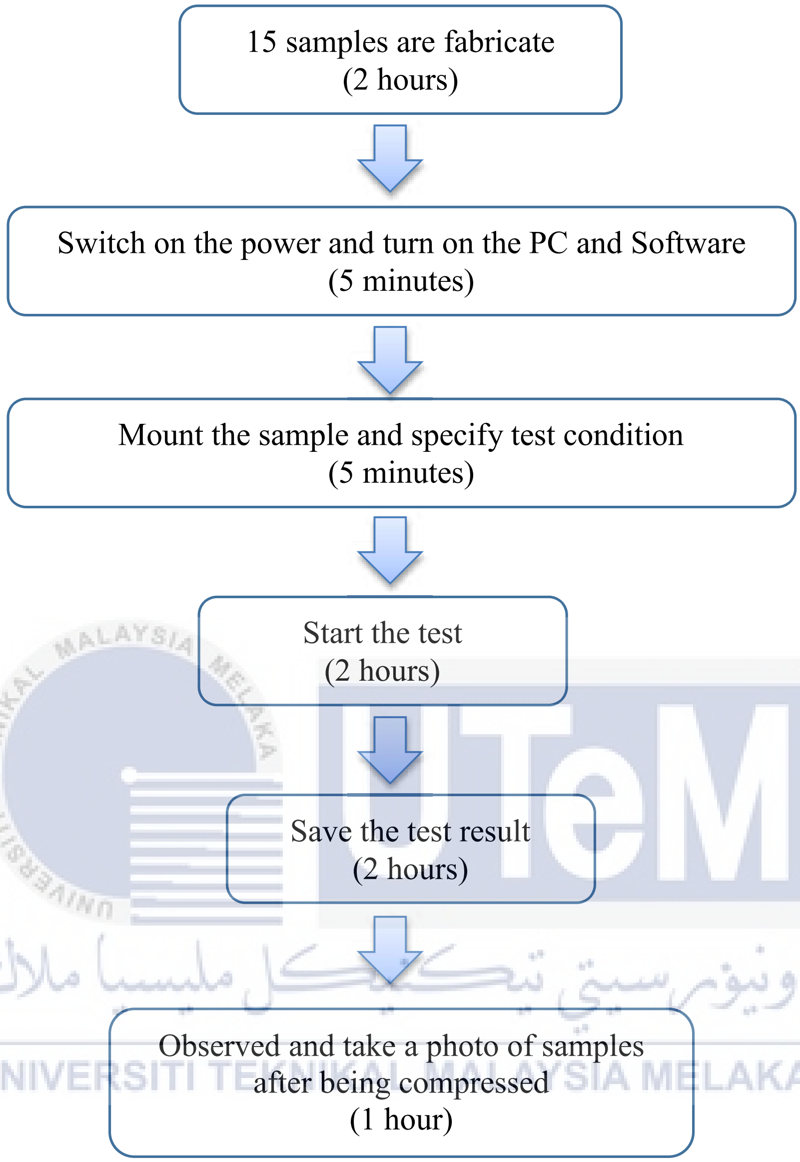
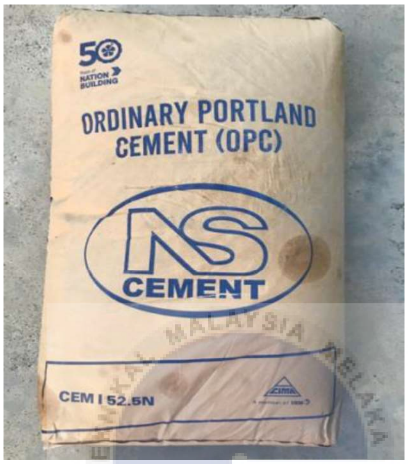


Figure 3.3 Flow Chart of Ratio Selection Process

3.7 Apparatus and Material Used Throughout Experiment

Table 3.2 Apparatus and Materials

Item	Description
1. Ordinary Portland Cement (OPC) 	- Purchased from Shukran Hardware shop at Durian Tunggal - RM15.50 (price per unit) - Total weight is 50 kg (per unit) - Commonly used cement in concrete construction.
2. Fine sand 	- Purchased from Shukran Hardware shop at Durian Tunggal. - RM6.00 (for 6 scoops) - Total weight is 30 kg - Fine sand is chosen for this experiment.

3. PET plastic aggregate  	- Collected from household. - Plastic bottle type is PET. - The most commonly used plastic. - Large amount of plastic is collected. - All the plastic is dried and cut in two sizes which are coarse aggregate and fine aggregate.
4. Weighing scale  	- Superior Mini Digital Platform Scale which made from China and purchased through online shop. - Blue black light display with tare range of full capacity. - Power: 2xAAA Batteries included - Has auto off function - Can measure maximum mass of 3kg - Platform size is 100 mm X 100 mm (LxW) - Scale size 130 mm X 109 mm X 20 mm (LxWxH)

5. Plastic mold 	- Microwavable food container - Purchased from Eco Shop - RM2.40 (per set) - Trapezoidal prism shape container - Has volume of 300 ml - Dimension of container is 102 mm X 102 mm X 45 mm (LxWxH)
6. Tank for water absorption test and moisture content 	- Type material: Plastic tank - Purchased from Eco Shop - RM2.40 (per unit) - Can be fitted for 6 unit of samples
7. Furnace 	- Type of machine: Nabertherm Muffle Furnace - With a flap door - Heating elements are radiate freely, implant in grooves to get high heating speed. - Maximum temperature is 1300 °C.

8. Shimadzu 	- Type of machine: Shimadzu Precision Universal Tester (Autograph AG-Xplus) - Material testing operation software: Trapezium X - Location: Material Testing Laboratory at Factory 1. - High-level controlled measurement performance. - High performance, easy to use and easy to operate.

3.8 Mass of Samples

Table 3.3 below shows the mass of every materials to be used in every sample production according to various composition of PET waste as aggregate. Aggregate percentage in every sample are calculated by mass. For water content, it is based on 50% of cement mass.

Table 3.3 Mass of Samples

Percentage of aggregate (%)	Mass of materials (g) for each sample				Total dry mass (g)	Total wet mass (g)
	Cement	Sand	Water	PET aggregate		
0	166.67	333.33	83.34	0	500	583.34
1	165.0	330.0	82.50	5	500	582.50
3	161.7	323.3	80.85	15	500	580.85
5	158.3	316.7	79.15	25	500	579.15
6	156.7	313.3	78.35	30	500	578.35
8	153.3	306.7	76.65	40	500	576.65
10	150.0	300.0	75.00	50	500	575.00

3.9 Sample Fabrication

The preparation and production of concrete mix containing plastic aggregate were fabricated in plastic food container with a volume of 300 ml as a mould . This was accomplished in accordance with the requirements of several different standards. In the process of creating each sample, a method of mixing altogether method was implemented. The chosen ratio used in this experiment is 1:2 (cement:sand) and percentage of aggregate are calculated and determined by weight (gram).

Before start fabricate the sample, the fine sand is make sure to be sieved. This action is to remove big size stone particles. According to the Figure 3.5, the first step is sieving the cement powder to ensure there is no presence of hydrated cement. Then prepared material was weighted according to the mix proportion as shown in Table 3.1 and Table 3.4. After weighing process, the materials are placed in a pail together to proceed with dry mixing. The amount of water to be added is depends on weight of cement. In calculation, amount of water added is 50% of cement weight. The process is continue with wet mixing by stirring all the materials together until it is become a new mixture. The mixture is then transferred into a plastic food container as a mould with the size of 102 mm X 102 mm X 45 mm (LxWxH). To avoid the air bubbles trap in the mixture, the mould can slowly be tapped by using fingers. Air trapped create blow holes within concrete. Its removal is necessary to reduce voids on the surface of concrete.

After fabrication is done, the samples are generally left for 24 hours to ensure it were hardened and solidify before being removed from the mold. On the next day, the samples are demoulded and ready to undergoes different testing operations. Figure 3.4 below shows sample fabrication process throughout the project.

a) The cement and fine sand are sieved.

b) All the prepared materials are weighted.

c) The weighted materials are place in a pail for dry mixing.

d) After adding water, the materials then proceed with wet mixing.

e) The mixtures are poured in the mold.

f) After the samples are dried, then it can be demoulded.

Figure 3.4 Sample Fabrication Process

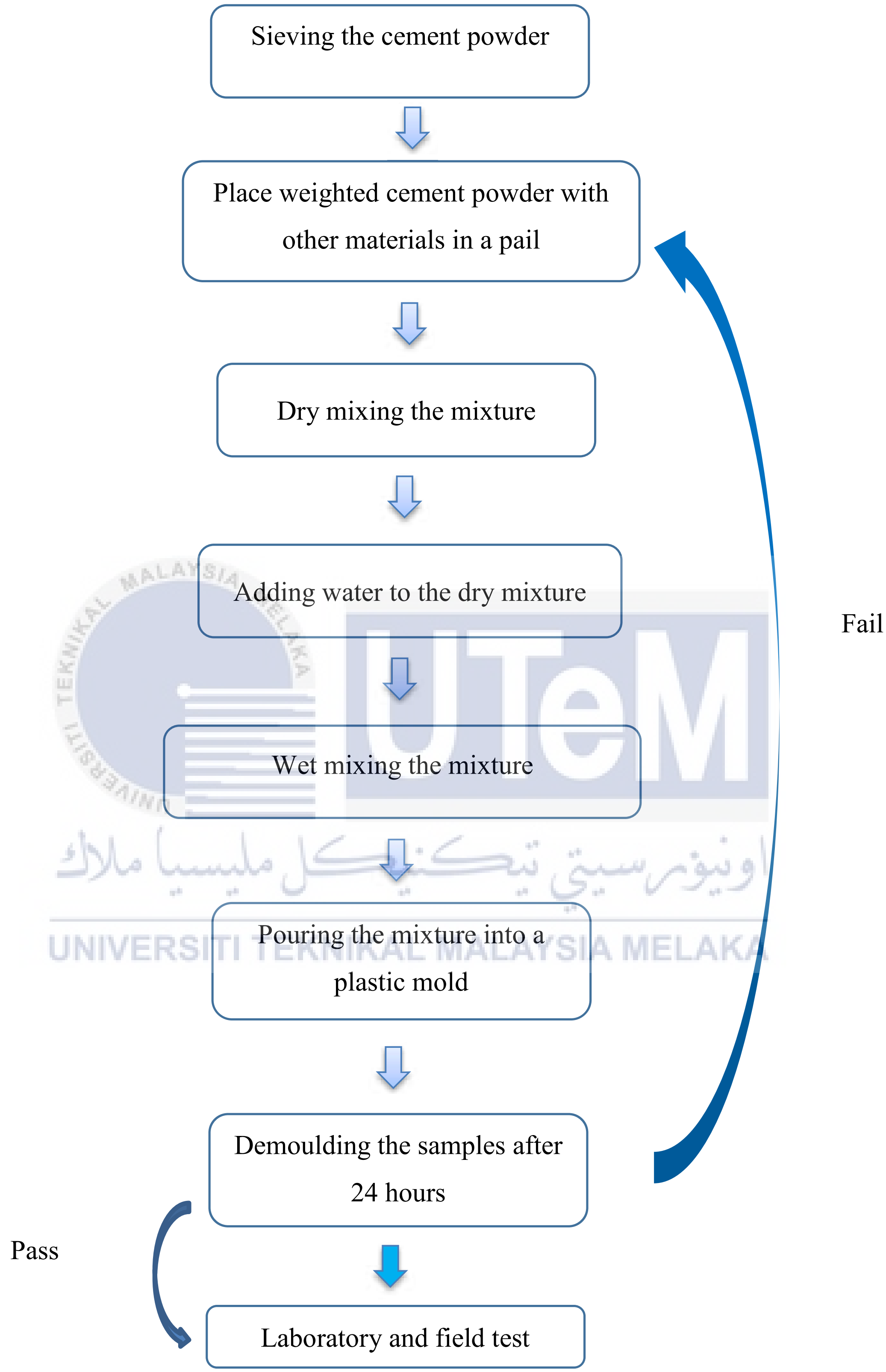


Figure 3.5 Flow Chart of Sample Fabrication

3.10 Laboratory and Field Testing

The samples after demolding undergoes few types of tests. Compressive strength test is done in Material Testing Laboratory at Factory 1, while for moisture content is done in Material Science Laboratory, which is located at Factory 2, FTKM, UTeM.

3.10.1 Compressive Strength Test

The major physical feature of a brick is its compressive strength, which is the one that is most typically applied in brick design. Compressive strength can be defined as ability of material or structure to hold weights on its surface without cracking or collapsing under the load's pressure. In layman, it is defined as best axial load resistance as shown in Figure 3.6. Through this compressive strength test, the maximum compression stress of a test cube sample or cylinder can withstand will be determined.

Figure 3.6 Free Body Diagram of Compressive Strength Test

Compression test machines (Shimadzu Precision Universal Tester), as shown in Figure 3.7, are often used to measure the strength of a material under crushing load until achieved failure. The procedure of this test is based on the ASTM 109M (2021) standard. After the data was obtained, it will be calculated using formula (3.1).

Equation 3.1

$$\text{Compressive strength}\left(\text{N/mm}^2\right) = \frac{\text{Force}}{\text{Area}}$$

Where F is represented as force or load applied on the sample in Newton (N) and A represents surface area of the sample in mm².

Figure 3.7 Shimadzu Precision Universal Tester at Factory 1, FTKMP UTeM

3.10.2 Water Absorption

Water absorption test analyses concrete surface water absorption rate or also known as sorptivity. In evaluating this test, the increase in concrete mass when the surface of the specimen are exposed to water are used to analysed the rate of water absorption. This test analyses how much water enters concrete samples when they are fully submerged in water.

Firstly, all the samples are make sure to be dried in room temperature. Then, the dried samples are weighted and initial mass are recorded. Next, the tank is filled with the tap water. The samples are then be submerged in the water in duration time of 24 hours. On the next day, the wet samples are taken out from the tank. Immediately it were being weighted and the final mass are recorded. The weighing process should be done in a short period of time. This action to ensure no water loss from the wet sample which can affect accuracy of data. Based on the tabulated data, rate of water absorption can be calculated using a specific formula. This test is shown in Figure 3.8 which The Schematic Representation of Absorption Test.

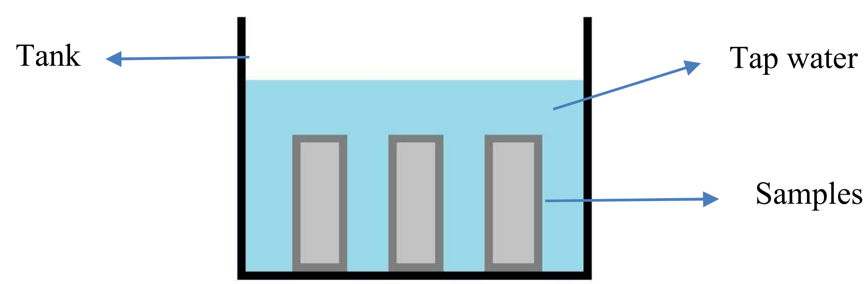


Figure 3.8 Schematic Representation of Water Absorption Test

The water absorption rate can be calculated using formula (3.2). The processs for water absorption are showed in Figure 3.9 and the flow chart is showed in Figure 3.10.

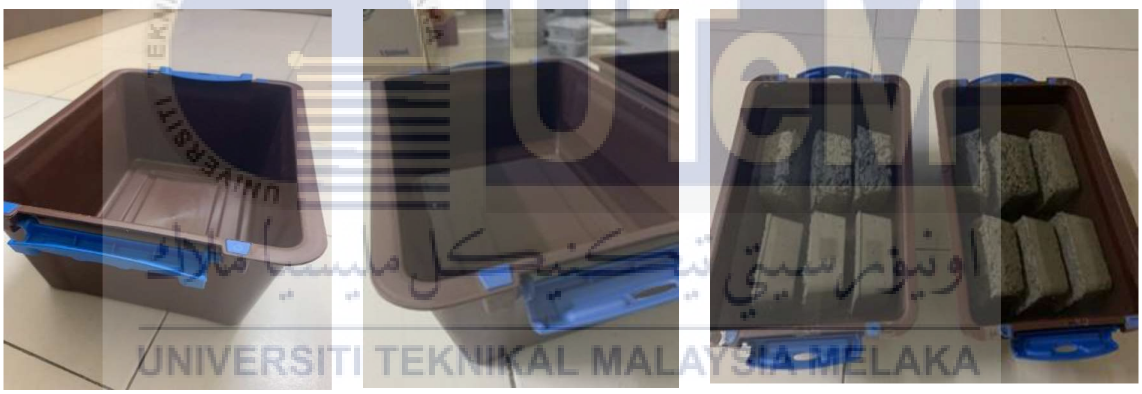
Equation 3.2

$$\text{Rate of Water Absorption} = \frac{W_f - W_0}{W_f} \text{X } 100\%$$

Where,

W_0 = Mass of dry sample in grams (g)

W_f = Mass of wet sample after 24 hours in grams (g)



a) Water tank is used.

b) The tank is filled with water.

c) The samples are submerged in the water for 24 hours.

Figure 3.9 Water Absorption Process

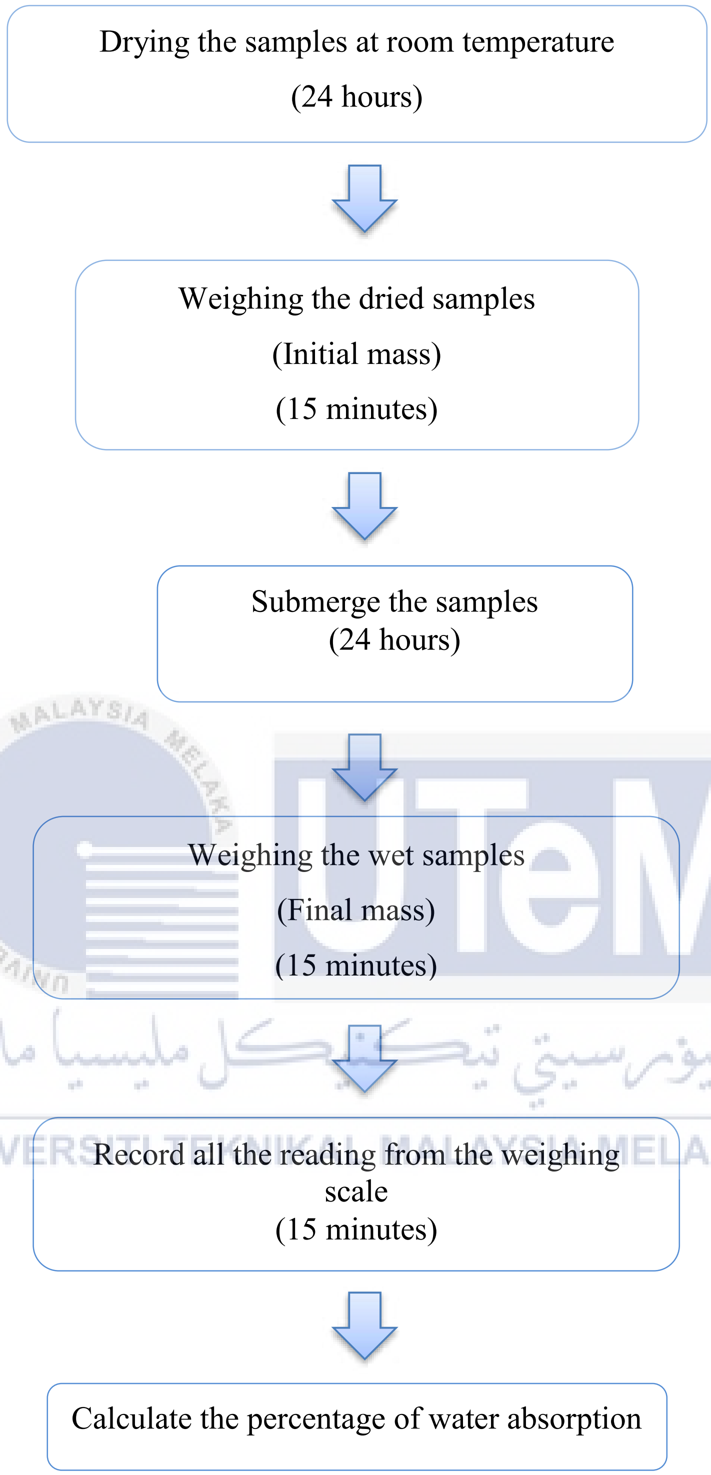


Figure 3.10 Process Flow Chart of Water Absorption Test

3.10.3 Density Test

Concrete density depends directly on the components with which it has been made off normally such as cement, sand, water and aggregates. The materials used in concrete construction will modify it properties in terms of compressive strength, resistance, texture and shape. Density will determine the types of concrete whether it is lightweight concrete, ordinary concrete or heavy concrete. Generally, the strength of the concrete increasing with the density of concrete. There are two major fact that influence the density of concrete which are aggregate type and the mix proportion.

In this experiment, PET plastic can be classified as lightweight aggregate which produce low density of concrete. To obtained density of each samples, directly use of formula can be implement. Average mass of samples must be recorded to calculate the density using the general formula (3.3).

Equation 3.3

$$\text{Density}, \rho = \frac{\text{Mass, g}}{\text{Volume, cm}^3}$$

3.10.4 Moisture Content Test

Moisture can be referred as the physical bound of water in its different phase vapor, liquid or solid. In making concrete, water is vital component. Water provides moisture which contribute to the increase concrete strength. The moisture that water provides also give strength to concrete. Even though water is one of the most vital things in concrete but it can give negative effect in enormous amount. In concrete construction, appropriate concrete drying solutions are necessary to ensure concrete strength and safety. Moisture content and water absorption are slightly different in terms of formula and the procedure.

Firstly, all the samples are make sure to be dried in room temperature. Next, the initial mass of samples are weighted and recorded. Then, the sample are placed in the Nabertherm Muffle Furnace for 110°C. The duration time for this step is 24 hours. On the next day, the samples are took out from the furnace. Lastly, the samples are immediately being weighted for final mass. The recorded data then being used for moisture content percentage calculation by using specific formula (3.4). Figure 3.11 below shows Process Flow Chart of Moisture Content Test.

Equation 3.4

$$\text{Percentage of Moisture Content} = \frac{W_0 - W_f}{W_0} \text{X } 100\%$$

W_0 = Mass of dry sample in grams (g)

W_f = Mass of wet sample after 24 hours in grams (g)

Drying the samples at room temperature
(24 hours)

↓

All the samples are weighted for initial mass.
(15 minutes)

↓

The samples are placed in the furnace for 110°C.
(24 hours)

↓

Samples are weighted. Final mass of samples are recorded.
(15 minutes)

↓

Values for moisture content are calculated and tabulated.
(1 hour)

Figure 3.11 Process Flow Chart of Moisture Content Test

CHAPTER 4

RESULT AND DISCUSSION

4.1 1ntroduction

The first thing to be discussed in this this section is the best ratio selection as mentioned in the previous subtopic, 3.6 Ratio Selection. Based on the objective of research, to determine the mechanical and physical properties of PET waste in concrete, there are four types of testing must be conducted which are compressive strength test, water absorption test, density test and moisture content test. After fabrication of samples were completed, the mechanical and physical properties changes on compressive strength, rate of water absorption, density profile and moisture content were being observed and the tabulated data from testing and calculation are analyzed. Besides, data obtained can clearly be justified based on every graph plotted. The graph plotted will shows the different pattern of every result obtained.

4.2 Best Ratio Selection

The compression test for the five ratios were performed and the results were tabulated as shown in the Table 4.1 below.

Table 4.1 Ratio Selection

Ratio	Maximum Force (kN)	Maximum Stress (Mpa)	Maximum Strain (%)
1:1	95.2305	13.1807	14.4892
1:2	95.0931	13.1617	13.0253
1:3	76.4671	10.5837	10.7427
1:4	54.3826	7.5270	22.7292
1:5	39.7686	5.5043	22.4115

For ratio selection, it is analyzed based on compression test result. In Figure 4.1, maximum force of ratio 1:1 and 1:2 samples showed the higher values compared to the others. Other ratio of samples shows more cracking which result in fracture which do not achieve software limit. This is proven that 1:1 and 1:2 samples have higher compressive strength than the others. In terms of maximum stress as shown in the Figure 4.2, 1:1 and 1:2 samples have a very small differences. By looking at maximum strain result as plotted in graph of Figure 4.3 below, 1:2 sample is lower than 1:1 sample. The result proved that ratio 1:2 sample is the second best ratio that can be used throughout the sample fabrication.

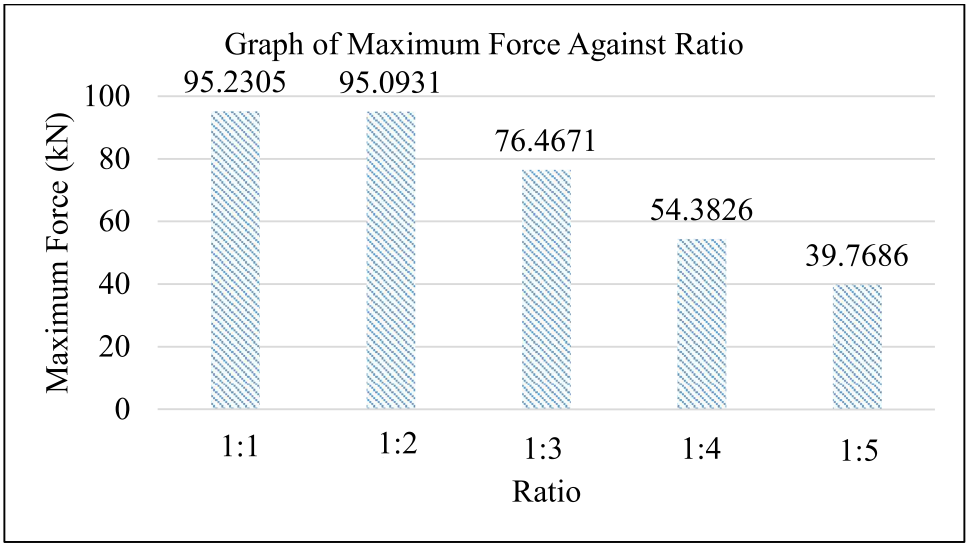


Figure 4.1 Effect of Ratio on Maximum Force

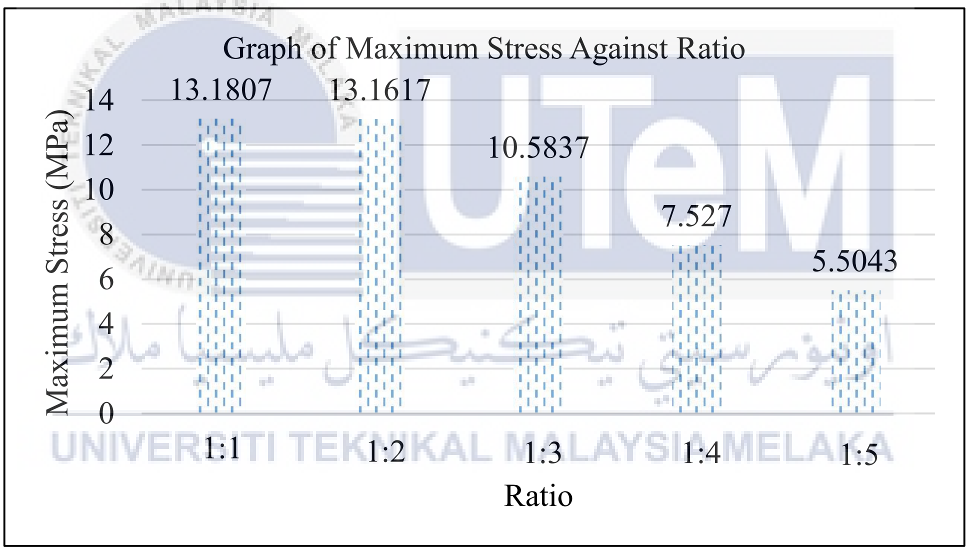


Figure 4.2 Effect of Ratio on Maximum Stress

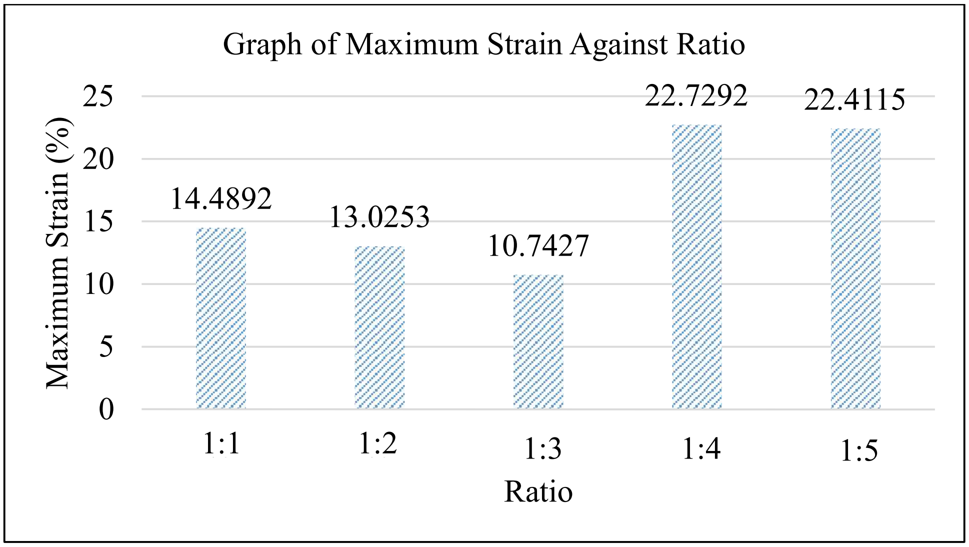


Figure 4.3 Effect of Ratio on Maximum Strain

4.3 Compressive Strength Test

The compression test for coarse and fine aggregate samples were conducted and the results were recorded as shown in the Table 4.2 and Table 4.3.

Table 4.2 Compression Test Result of Coarse Aggregate

Percentage of Aggregate (%)	Maximum Force (kN)	Maximum Stress (MPa)	Maximum Strain (%)
0	95.0931	13.1617	13.0253
1	95.1594	12.2881	9.66475
3	95.0679	12.2763	19.1537
5	95.0184	12.2699	27.8318
6	95.0212	12.2703	38.8833
8	95.0400	12.2727	42.7707
10	95.0586	12.2751	59.5413

Table 4.3 Compression Test Result of Fine Aggregate

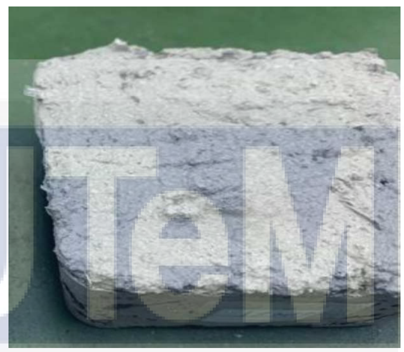
Percentage of Aggregate (%)	Maximum Force (kN)	Maximum Stress (MPa)	Maximum Strain (%)
0	95.0931	13.1617	13.0253
1	95.1475	12.2866	13.7391
3	95.0477	12.2737	15.1808
5	95.0437	12.2732	18.1581
6	95.0470	12.2736	21.1423
8	95.0196	12.2701	29.6760
10	95.0399	12.2727	34.3993

In order to measure the compressive strength properties and low ductility materials or elastic of brittle materials, the compressive strength test are crucial. This test characterize the compressive properties of materials. In this research, a 100kN Compression Test Machine is used. All the samples tested achieved software limit during this test which result in the same range value of the maximum force and maximum stress. Based on the data tabulated in Table 4.2 and Table 4.3, the maximum force are in the range values of between 95.0184kN and 95.1594kN. For the maximum stress, the range values is in between 12.2701MPa and 12.881MPa. By referring to the ratio selection result in the previous chapter, ratio 1:2 of the samples make it strong enough to be compressed by 100kN machine even though PET aggregates were added in the sample fabrication which lead to the achievement of software limit and the data obtained are almost the same. From the results obtained, the addition of PET aggregates of different percentages give a different values of maximum strain.

Based on the Figure 4.5 shown below, coarse aggregates graph shows that the higher the percentage of aggregate, the higher the maximum strain. Strain can be defined as deformation of a material from stress. To be clear, it is a ratio of the change in the length to the original length. A positive value correspond to a tensile strain, while negative value is compressive. By observing the samples physically, the higher the percentage of aggregate, the rougher the surface of the samples. Besides, the texture is relatively smooth and glassy for low percentage of aggregate which provides less inter-particle frictional resistance than the rougher one. Smooth surface of samples contributes to the low maximum strain. The result shows that rough surface of samples develop strong bondage between of aggregates and the cements which result in high maximum strain. The ductility increases as the percentage of PET aggregate increases. It is analyzed by observing the failure mode of different tested samples.

Fine aggregates graph also shows that the maximum strain increasing with the percentage of PET aggregate. Physical observation of the samples justify that roughness of the surface increasing with the percentage of PET aggregate. When comparing to the coarse aggregate, the highest maximum strain value is 59.5413%, while for fine aggregate sample is 34.3993% which lower than the coarse aggregate sample. Comparing to previous compression test for ratio 1:2 of reference sample with no aggregate, the maximum strain is 13.0253 which lower than 1% 0f fine aggregate but higher that 1% of coarse aggegate.

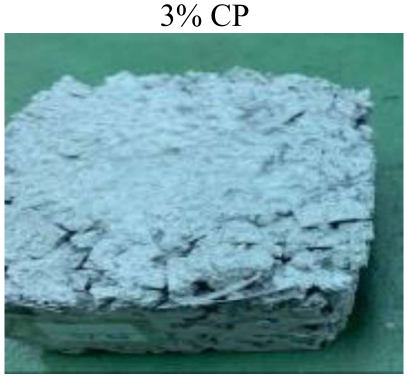
1% CP



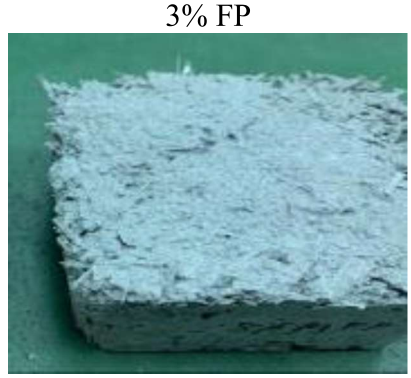
1% FP

3% CP

3% FP



5% CP



5% FP

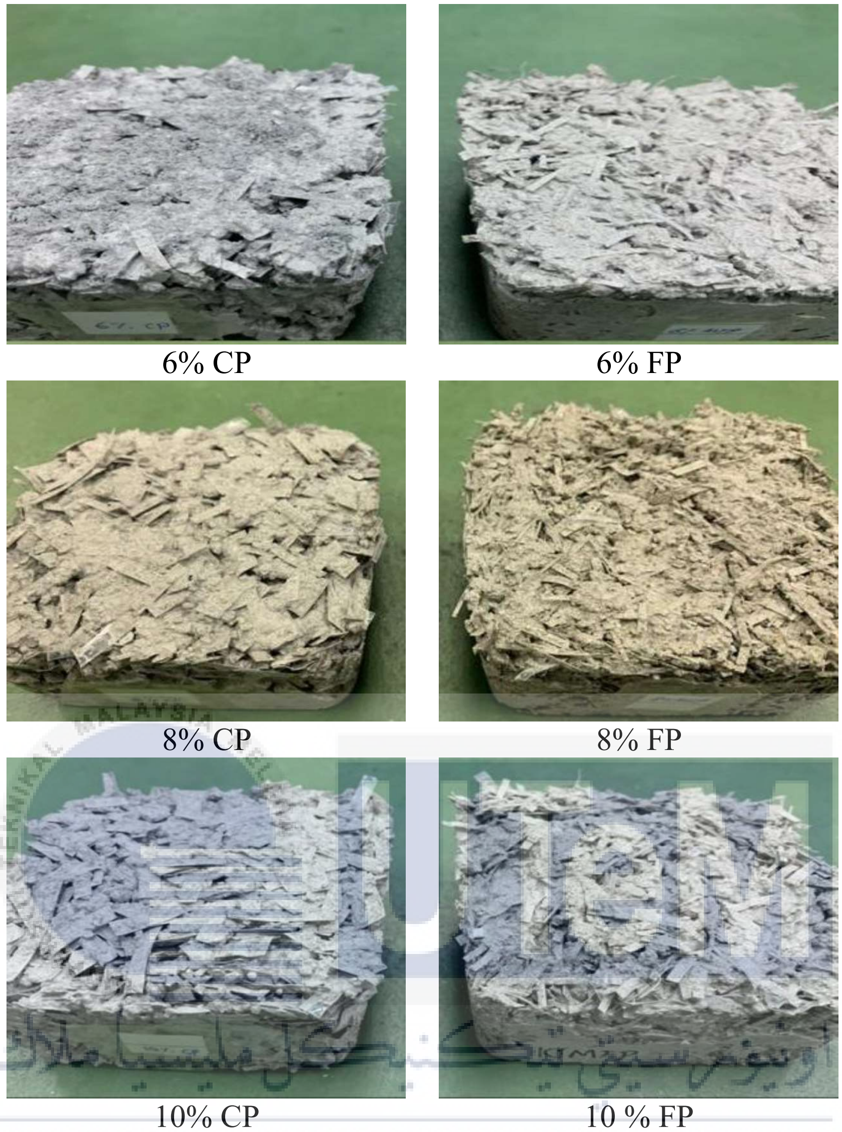
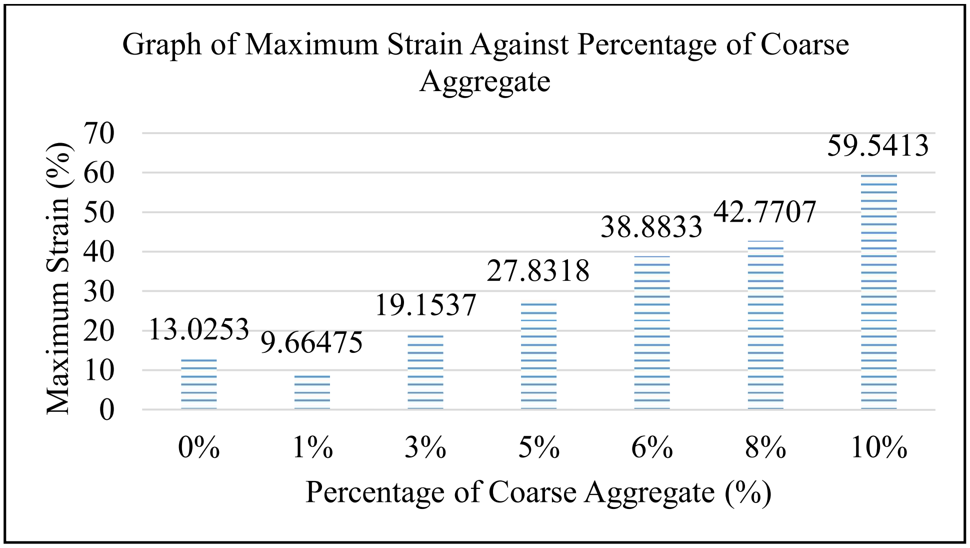
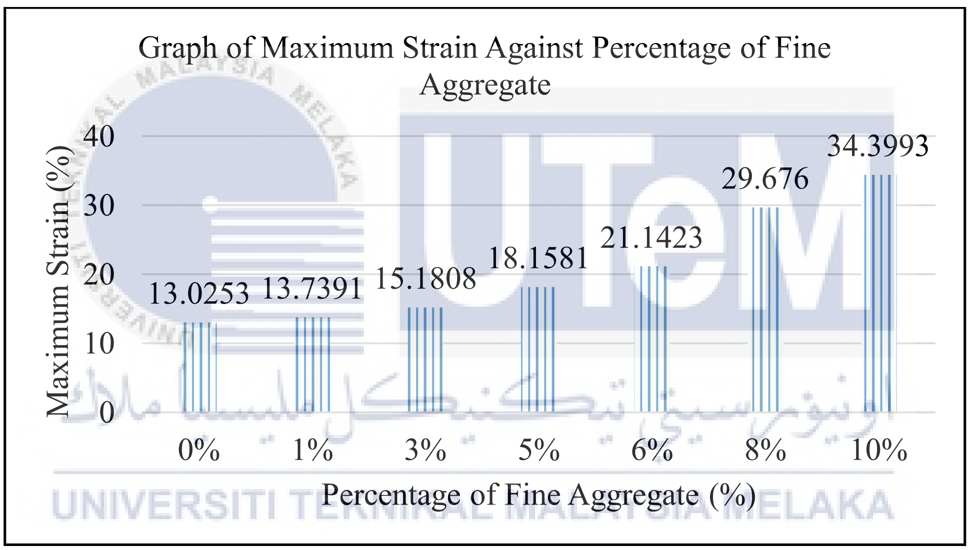


Figure 4.4 Surface of Coarse and Fine Aggregate Samples (CP is coarse plastic while FP is fine plastic)



(a)



(b)

Figure 4.5 Effect of Percentage of Aggregate (%) to the Maximum Strain (%) (a) Coarse and (b) Fine

4.4 Water Absorption Test

The water absorption test for coarse and fine aggregate samples were conducted and the results were tabulated as shown in the Table 4.4 and Table 4.5.

Table 4.4 Water Absorption Test Result of Coarse Aggregate

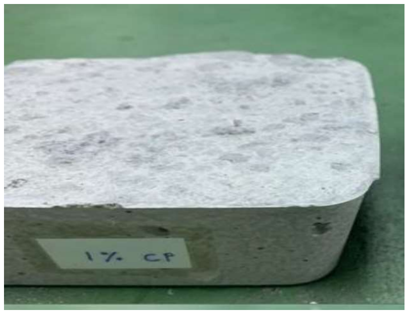
Percentage of Aggregate (%)	**Initial Mass (W_0), g**	**Final Mass (W_f), g**	**W_f - W_0**	**Rate of Water Absorption (%)**
0	479.3	459.7	19.6	4.26
1	544.3	579.7	35.4	6.12
3	514.0	551.1	37.1	6.73
5	508.0	549.3	41.3	7.52
6	501.0	545.8	44.8	8.21
8	452.3	504.0	51.7	10.26
10	377.8	431.1	53.3	12.36

Table 4.5 Water Absorption Test Result of Fine Aggregate

Percentage of Aggregate (%)	**Initial Mass (W_0), g**	**Final Mass (W_f), g**	**W_f - W_0**	**Rate of Water Absorption (%)**
0	479.3	459.7	19.6	4.26
1	499.0	538.2	39.2	7.28
3	487.4	528.2	40.8	7.72
5	472.0	513.8	41.8	8.14
6	459.9	503.6	43.7	8.68
8	445.5	492.1	46.6	9.47
10	413.0	464.6	51.6	11.11

Based on the graph plotted in Figure 4.7 below, the pattern of graph shows positive relationship where the rate of water absorption increasing with percentage of PET aggregate. The main reason is because higher percentage of PET aggregate will lead to increase of concrete voids due to lack of assembly between PET and cement paste. PET aggregate creates its own porosity and different from original concrete. From Figure 4.6, coarse aggregate sample shows more voids compared to fine aggregate. This will result in more amount of water to be enter and trapped within the voids. Due to water absorption, the final mass of samples will increase.

Besides, started from the sample fabrication is actually make voids and pores by air bubbles difficult to avoid. The reason is because addition of PET aggregate create gap between cement as it is not compressed by any load to fully fill the mold. As the consequences, it will cause non-uniform mass of samples and affect the rate of water absorption. Reference sample (0% PET aggregate) has the lowest rate of water absorption. The compact structure as without plastic waste is the main reason as there is less air bubble trapped and voids that lead to low water absorption.


1% CP


1% FP


3% CP

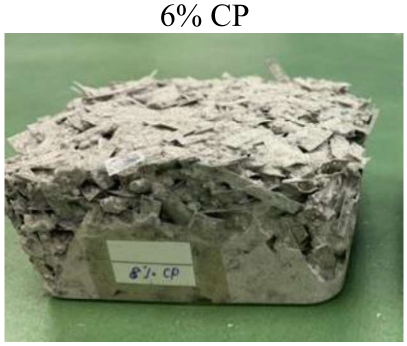

3% FP

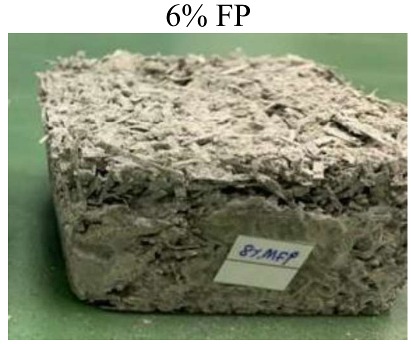

5% CP


5% FP


6% CP

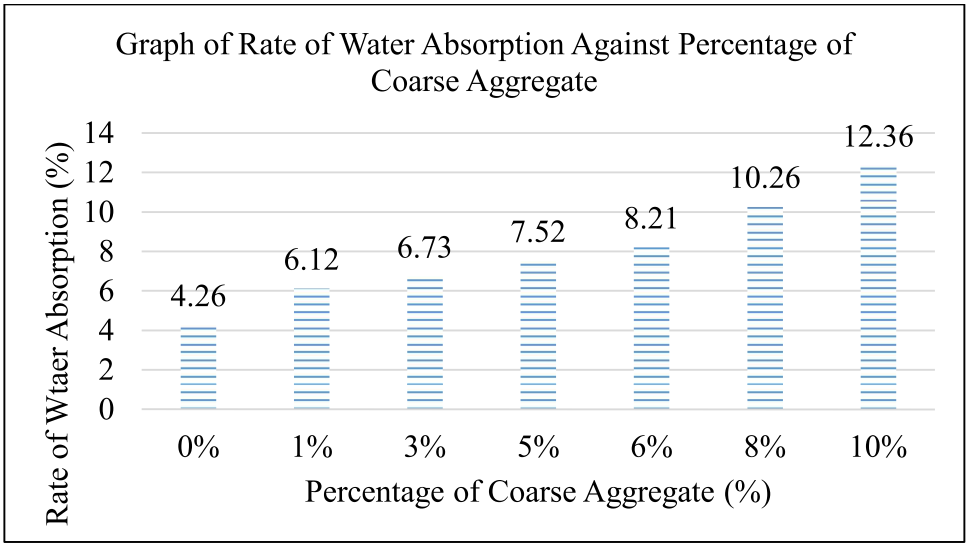

6% FP


8% CP

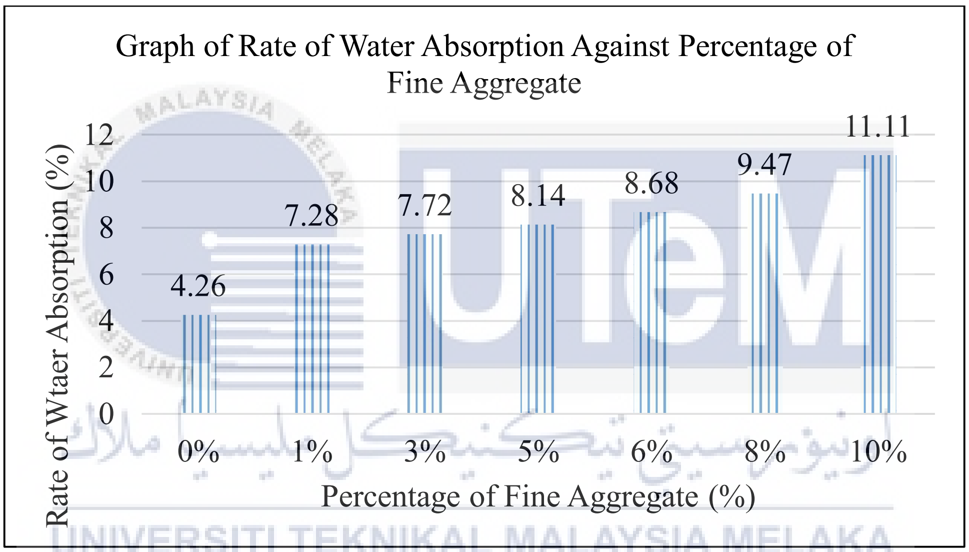

8% FP

10% CP 10 % FP

Figure 4.6 Physical Comparison of Coarse and Fine Aggregate Samples (CP is coarse plastic while FP is fine plastic)



(a)



(b)

Figure 4.7 Effect of Percentage of Aggregate to the Rate of Water Absorption (a) Coarse and (b) Fine

4.5 Density Profile

The density test for coarse and fine aggregate samples were conducted and the results were tabulated as shown in the Table 4.5 and Table 4.6.

Table 4.6 Density Profile Test Result of Coarse Aggregate

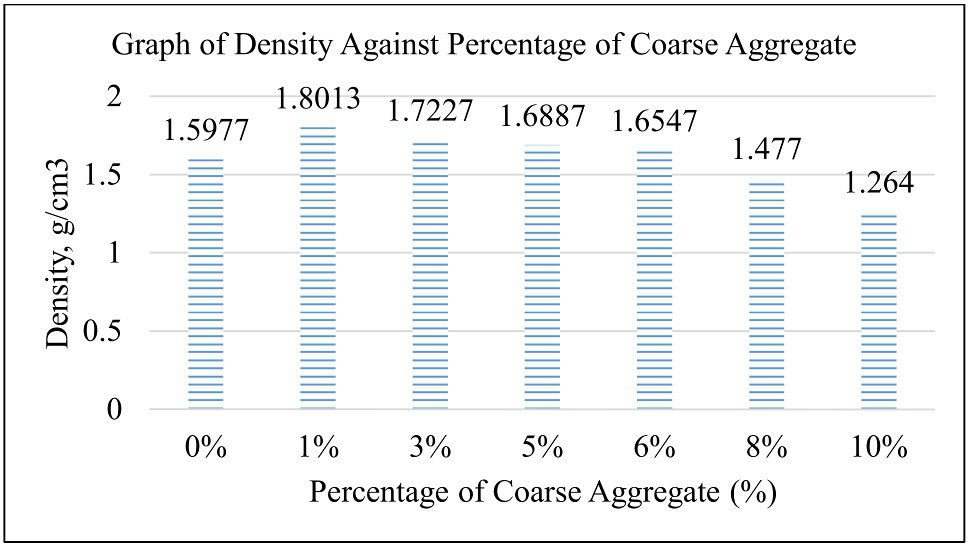
Percentage of Aggregate (%)	Mass of each sample, g			Average mass, g	Density, g/cm^3
	Sample A	Sample B	Sample C		
0	471.7	485.9	480.3	479.3	1.5977
1	544.3	536.9	540.0	540.4	1.8013
3	514.0	520.1	516.2	516.8	1.7227
5	508.0	501.8	509.9	506.6	1.6887
6	501.0	490.5	497.6	496.4	1.6547
8	452.3	431.7	445.3	443.1	1.4770
10	377.8	386.4	373.5	379.2	1.2640

Table 4.7 Density Profile Test Result of Fine Aggregate

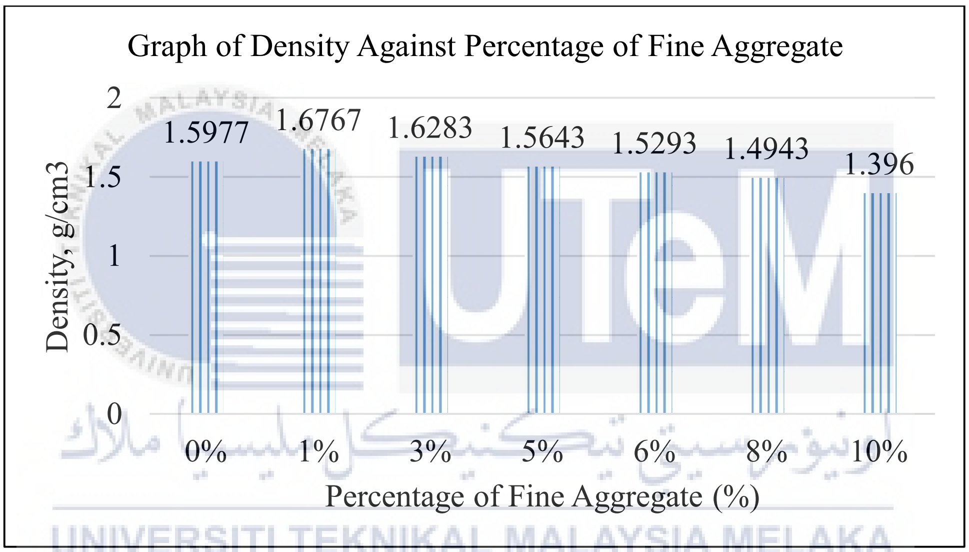
Percentage of Aggregate (%)	Mass of each sample, g			Average mass, g	Density, g/cm^3
	Sample A	Sample B	Sample C		
0	471.7	485.9	480.3	479.3	1.5977
1	499.0	508.0	502.1	503.0	1.6767
3	487.4	490.3	487.9	488.5	1.6283
5	472.0	465.5	470.3	469.3	1.5643
6	459.9	455.9	460.5	458.8	1.5293
8	445.5	450.7	448.7	448.3	1.4943
10	413.0	425.3	418.2	418.8	1.3960

Generally, PET aggregates have lightweight properties due to low density. By adding PET to the concrete, it will reduce the density of concrete and make it lighter than normal concrete. Every percentage of PET aggregates are calculated according to the mass of normal concrete. Even though it is calculated by mass, but still in terms of volume, shredded plastic used is in a big amount as it is lightweight. The higher the percentage of PET aggregate, the lower the usage of concrete and fine sand. Based on the graph plotted in Figure 4.8, the relationship can be made is the higher the percentage of aggregate, the lower the density of the samples. For the tabulated data in Table 4.6 and 4.7, the values of density can be directly calculated using general formula which is mass of sample divided by volume of the mold.

The samples with PET aggregates can be consider as lightweight concrete as all the density of samples are in range of 0.8 g/cm^3 – 2 g/cm^3.



(a)



(b)

Figure 4.8 Effect of Percentage of Aggregate to the Density (a) Coarse and (b) Fine

4.6 Moisture Content Test

The moisture content test for coarse and fine aggregate samples were conducted and the results were tabulated as shown in the Table 4.7 and Table 4.8.

Table 4.8 Moisture Content Test Result of Coarse Aggregate

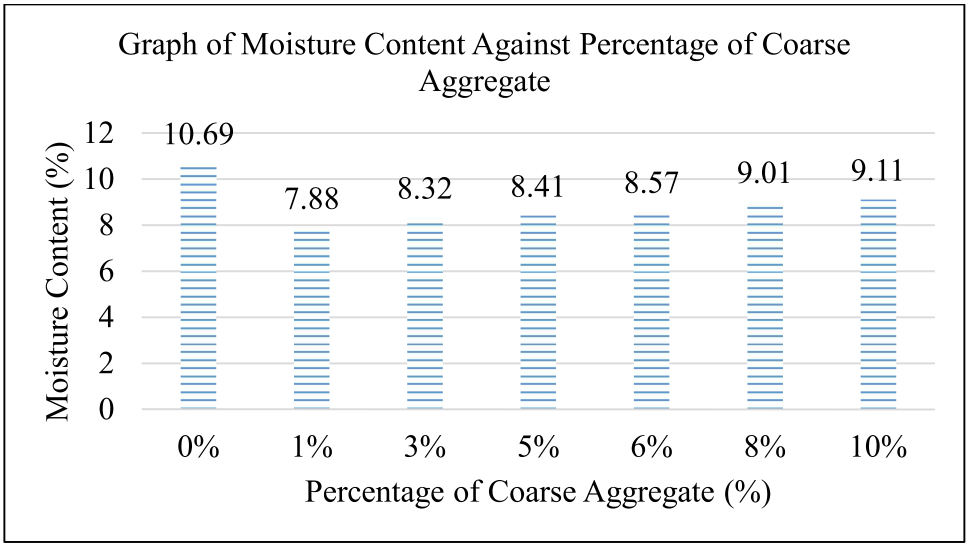
Percentage of Aggregate (%)	**Initial Mass (W_0),g**	**Final Mass (W_f),g**	**W_0 - W_f**	**Moisture Content (%)**
0	492.5	439.85	52.65	10.69
1	558.7	514.70	44.00	7.88
3	528.8	484.80	44.00	8.32
5	515.0	471.70	43.30	8.41
6	513.4	557.40	44.00	8.57
8	467.0	424.90	42.10	9.01
10	393.8	357.90	35.90	9.11

Table 4.9 Moisture Content Test Result of Fine Aggregate

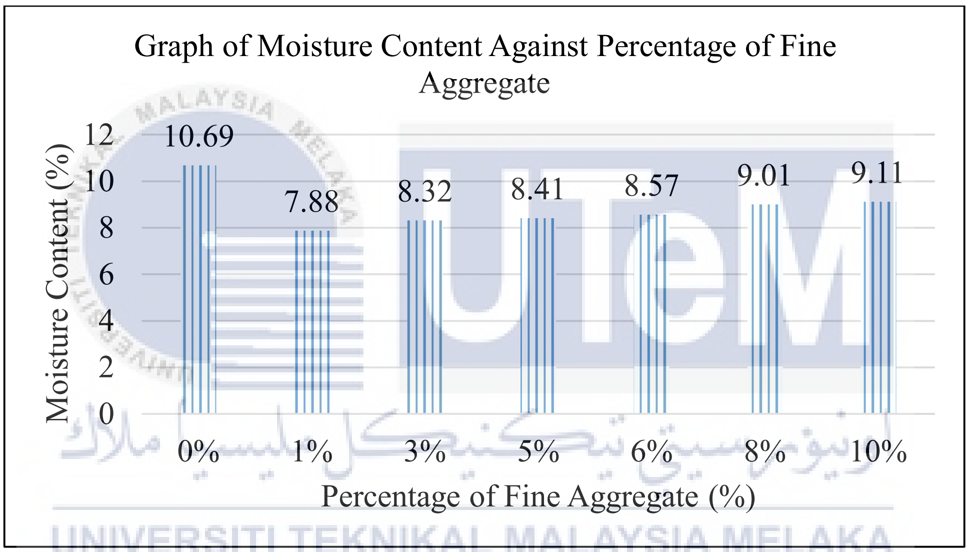
Percentage of Aggregate (%)	**Initial Mass (W_0),g**	**Final Mass (W_f),g**	**W_0 - W_f**	**Moisture Content (%)**
0	492.5	439.85	52.65	10.69
1	512.7	463.30	49.40	9.64
3	502.6	455.50	47.10	9.37
5	500.0	453.30	46.70	9.34
6	493.2	448.70	44.50	9.14
8	461.8	419.60	42.20	9.14
10	396.7	360.70	36.00	9.07

In this research, moisture content test also be carried out. Water absorption test and moisture content test are not the same in terms of formula and the method to carry out the test. Generally, to determine the moisture content, all the dry samples need to be expose to the heat by placing in the furnace for 24 hours. This step eliminate water content in the samples which result in reduction of final mass. Based on the graph tabulated in Figure 4.6, for coarse aggregate, the moisture content percentage increasing with percentage of aggregate. As mentioned in the previous test of water absorption, coarse PET concrete have numerous voids which increase the rate of water absorption and caused amount water elimination also higher. Different from fine aggregate as the moisture content percentage decreasing with the percentage of aggregate. The reason is because it has less voids due to compact structure and lead to less water eliminate when undergoes evaporation process in the furnace. Evaporation process took place faster in fine aggregate samples.

Comparing to the reference sample (0% aggregate), it has the highest value of moisture content. High moisture content will reduced the strength of concrete. The relationship can be made is when the moisture content increase, the compressive strength will decrease.



(a)



(b)

Figure 4.9 Effect of Percentage of Aggregate to the Moisture Content (a) Coarse and (b) Fine

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, all the objectives of this project have been successfully achieved. The problem were resolved after completed the project and report. The process of sample fabrication and all the testing procedure of this projects were described and defined in details. By referring to the first objective of this project, plastic waste mixture (PET) in concrete production by using mixing method which are mixing all the materials with various plastic waste mixture (PET) composition are successfully produced. All the samples are produced with various percentage of 1%, 3%, 5%, 6%, 8% and 10% composition of plastic waste mixture (PET).

The effect of the influence of waste mixture (PET) in lightweight concrete based on the composition of waste mixture (PET) and preparation method for physical and mechanical properties in terms of compressive strength, water absorption, density and moisture content are explained. After completed the research, it can be concluded that the best ratio for concrete production is 1:2.

Based on the testing result and analysis, the coarse aggregate with size of 5 mm – 7 mm showed the ideal size for concrete PET production. From overall tested samples, 10% coarse aggregate of PET sample is chosen as the best sample throughout the research. It is due to higher maximum strain which 59.5413%, slow down the deformation process and give the highest strength to PET concrete. Furthermore, 10% of coarse aggregate sample have the lowest density which is 1.2640 g/cm^3.

In analyzing whether the samples is lightweight concrete or not, back to the definition of lightweight concrete which have oven-dry density of range in between 0.8 g/cm^3 – 2.0 g/cm^3 as compared to normal weight concrete and heavy weight concrete. All the samples in this research can be categorized as lightweight concrete. From the moisture content test, the percentage of water loss not exceed 11%. This shows that only small difference are made by placing the samples in the oven. The density is decreasing with the mass, which is directly proportional to each other. This lead to lower density and made the samples to be in lightweight properties.

5.2 Recommendation

In the sample fabrication, the preparation method must include pressing compaction technique. Pressing compaction technique can be implement by placing a certain load on the top of samples during fabrication process. This step to reduce the gap between aggregate and other materials. Besides, it will reduce the voids and pores in the samples which lead to better result during implementation of different testing.

For the compressive strength test, the 100kN Compression Test Machine can be substitute with higher load capacity of machine. The main reason is to get the result of maximum force of each sample with different percentage of PET aggregate. Values of compressive strength can be calculated if different values of maximum force were obtained during the testing.

Throughout the research, only mixing all materials method are being used. As to get comparative results in terms of method of sample fabrication, layering method can be implement. Layering method can be done by using layer filling between plastic waste and other mixed material with various plastic waste mixture (PET) compositions. The result from sample fabrication showed that mixing method produced rough surface of sample when high percentage of PET aggregate is used. In general, layering method would produce a smooth surface as the layer filling is between the aggregate and other mixed materials which do not affect the sample surface.

Based on the conclusion, the coarse aggregate contribute to higher strength of tested sample. By increasing the size of coarse aggregate which more than 7 mm, this may result in higher maximum strain and shows increasing pattern of graph until achieved a limit where the size cannot be increased further.

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APPENDICES

APPENDIX A Gantt Chart PSM 1

No.	Month(2022)	March				April				May				June			
	Week / Activity	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	Choosing PSM Title and Attend PSM Briefing																
2	Overview of Thesis Project																
3	Identify Objective and Scope																
4	Preparation of Literature Review																
5	Develop the Methodology for PET-Concrete Production																
6	Preparation of PSM 1 report																
7	Completing Full Report of PSM 1 with Correct Format																
8	Correction of PSM 1 Report																
9	Submission of Final PSM 1 Report and e-Logbook																
10	Upload Presentation Slide with Recorded Video Link																
11	Q&A Session with Panel																
12	Upload Corrected Report of PSM 1																

APPENDIX B Gantt Chart PSM 2

No.	Month (2022)	October				November				December				January (2023)			
	Week / Activity	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	Discussion on work scope	■	■														
2	Setup experiments and finding the best parameter			■	■												
3	Develop production methodology				■	■											
4	Testing of samples based on various ratio				■	■	■										
5	Conduct various test according to the objectives						■	■	■	■							
6	Result interpretation and analysis									■	■	■					
7	Preparation of PSM 2 report										■	■	■				
8	Completing Full Report of PSM 2 with Correct Format											■	■				
9	Correction of PSM 2 Report													■	■		
10	Submission of Final PSM 2 Report and e-Logbook														■	■	
11	Presentation and Q&A Session														■	■	
12	Upload Corrected Report of PSM 2															■	■